KISSsys 03/2018 - Template

Calculation with Load Spectrum template
General Information

KISSsys allows the user to build a complete gear box or drive train in a single file. Calculations can then be performed easily for the whole system using KISSsoft modules. KISSsys can be used to make an analysis of a complete system using a load spectrum. This can be done with the help of a special template for load spectrum calculation. Using the template, the user is able to define load cases for the system and perform the calculation for all the components with a user defined load spectrum. The lifetime calculations with spectrum are available for the same components as in KISSsoft level. The safety factors and lifetimes of different gears and bearings can be calculated using the spectrum. Additionally, shaft fatigue safeties can be calculated using the spectrum (DIN743). The rest of the components (where the calculation with spectrum is not possible) are considered only as a check of the "weakest" component.

The load spectrum template functionality allows the following types of calculations:

1) Calculation of a gearbox with user defined load (reference/initial nominal load)
2) Calculation of a gearbox with a single load level taken from the load spectrum.
3) Calculation of a gearbox with a load spectrum
4) In addition to the option in number KISSsoft calculations can be exported
5) The complete load spectrum calculation can be combined with efficiency calculation, housing stiffness consideration, modal analysis and contact analysis.

This document describes how to implement and to use the functionality. There is a possibility to extend the spectrum with additional values or setups, this document will also describe where and how the user is able to do this (requires administrator right to be activated).
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1 What can be calculated

1.1 The following can be calculated with the load spectrum template

<table>
<thead>
<tr>
<th>Element</th>
<th>Safety factors</th>
<th>Lifetime</th>
<th>Damages</th>
</tr>
</thead>
<tbody>
<tr>
<td>Spur-, Helical-, Planetary-</td>
<td>SF, SH, SSint, SB</td>
<td>LF and LH per each gear</td>
<td>DF and DH against required, against calculated lifetime</td>
</tr>
<tr>
<td>and Crossed helical gears</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bevel gears</td>
<td>SF, SH, SSint</td>
<td>LF and LH per each gear</td>
<td>DF and DH against required, against calculated lifetime</td>
</tr>
<tr>
<td>Bearings</td>
<td>fs (static safety factor, S0)</td>
<td></td>
<td>Against required, against calculated lifetime</td>
</tr>
<tr>
<td>Shafts</td>
<td>SD (fatigue) and SS</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(static) in the defined cross sections</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Other components</td>
<td>Weakest component per pin</td>
<td>Weakest component per pin</td>
<td></td>
</tr>
</tbody>
</table>

1.2 How to calculate

Calculations are performed using KISSsoft and KISSsys functionalities. All the results according to the spectrum (final results) are calculated using KISSsoft spectrum functionalities (except for bearing modules). If requested, the KISSsoft files can be also exported with the spectrum inside to check later separately. After the calculations, the results are written in text- or other types of files and exported to the model folder from the program.

2 Requirements

2.1 KISSsoft and KISSsys modules

To perform the calculations, the following KISSsoft modules are required additionally to at least one strength calculation method for the elements which are needed to be calculated.

- Gear lifetime and safety factors with load spectrum: ZZ1 (Load spectra) including modules Z16, Z16a, Z18, Z18a
- Shaft calculation with load spectrum: WA8 (Load spectra) including modules W01s, W06s
- KISSsys full version for template implementation and setup: SYS module K11c

3 Flow chart

Yellow fields are only for single load case. Gray fields are only for load spectrum case
Load Spectrum
table

Definition

Manual

Read from
file

Calculations

Single load
level

With spectrum

Case
number

Set load step
Kinematics

Details

yes

KISSsoft

Save

no

Nof Steps

Create
element files

KISSsoft

Nof Steps

Save

Messages

FND
4 Import load spectrum functionality

4.1 Open templates

An existing KISSsys model can be opened or a new model can be created for the load spectrum calculation to be added. The administrator mode needs to be activated using “Extras/Administrator” as shown below to be able to add new functionalities.

![Open a model and change to administrator mode](image1)

Figure 1. Open a model and change to administrator mode

The template for the load spectrum calculation is included in the default templates. The template will be imported just by pressing the icon shown below.

![Importing "LoadSpectrumTemplate.ks"](image2)

Figure 2. Importing "LoadSpectrumTemplate.ks"
The template contains only one table element called "LoadSpectrum" by default, which includes all the functionalities (it is possible to change the name of the table during or after insertion). It is possible to insert several templates as shown below.

![Figure 3. Several templates imported in the three structure](image)

After this, the function “DefinitionDialog” needs to be run at least once, before switching off the administrator mode again (See more details in chapter 5.2.1).

5 Functionality

5.1 General

The user needs to define at least three things for the load spectrum (Frequency/Hours, Torque and Speed). Input values can be given to the desired “kSysSpeedOrForce” point (a power input or a power output) and values can be entered as absolute values or as fractions of nominal load.
Note that values can be only given for those “kSysSpeedOrForce” points where these values are constrained. User may select if frequencies (fractions of one) or hours are defined in the spectrum. In case if frequencies are defined also total required lifetime needs to be set. If hours are to be defined, total operational (required) lifetime and frequencies per step are calculated automatically.
In case if there is also a gear selection (e.g. vehicle gear boxes) to be considered user may define this in the “DefinitionDialog”. Additionally to this, extra variables can be considered in the spectrum.

5.2 Available Functions

"LoadSpectrum" table includes several functions to operate. Some of the functions are for definition, some to perform calculations and some to write results. The order to operate is normally as following:

1. DefinitionDialog
2. ImportSpectrum
3. ExportSpectrum
4. CalculationDialog

Hidden functions are automatically operated during the calculation and it is not recommended to use these manually. (Note: if you are still in administrator mode, you will see additional functions (hidden), we therefore recommend to switch of the administrator mode after the definition of the spectrum)

<table>
<thead>
<tr>
<th>Name</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>DefinitionDialog</td>
<td>This function will define types and style of data used in the spectrum.</td>
</tr>
<tr>
<td></td>
<td>When this function is used and “OK” pressed data in spectrum table</td>
</tr>
<tr>
<td></td>
<td>is initialized if you have administrator mode activated!</td>
</tr>
<tr>
<td>ImportSpectrum</td>
<td>This function can be used in any time to read in spectrum data from a file</td>
</tr>
</tbody>
</table>
The load spectrum information can be written in a "*.csv" file including the header.

Execute load spectrum calculation. You should finish the proper definition for the load spectrum before calling this function.

5.2.1 “Define” → “DefinitionDialog“

First point is to create a load spectrum. That can be done through definition dialog which is called “DefinitionDialog”. The function can be executed with a right mouse click on the “Load spectrum Template” and selecting it:

![DefinitionDialog](image)

Figure 4. Executing the function “DefinitionDialog”

Executing the function will open a dialog to setup the data:

![Load spectrum definition dialog](image)

Figure 5. Load spectrum definition dialog
### Table 3 Load spectrum definition dialog, fields

<table>
<thead>
<tr>
<th>Field</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>Definition:</td>
<td>Define load spectrum manually or import from a “*.csv”-file.</td>
</tr>
<tr>
<td>No. of bins:</td>
<td>In case of manual definition number of load steps to be given. (Inactive if import from a file selected)</td>
</tr>
<tr>
<td>Frequency type:</td>
<td>Select if Frequency (percentages/fractions of one) or absolute operation hours are to be defined</td>
</tr>
<tr>
<td>Required lifetime [h]:</td>
<td>Total required lifetime (operational time) needs to be given if duration type &quot;Frequency&quot; is selected</td>
</tr>
<tr>
<td>Spectrum type (speed and torque):</td>
<td>Select definition of Torque and Speed as absolute values or percentages/fractions of user defined nominal load. (Note! If you want to define spectrum as absolute values take care of signs for speed and torque / direction of rotation and Input or Output)</td>
</tr>
<tr>
<td>Speed defined to:</td>
<td>Select from list “SpeedOrForce” point where you want to define speed for spectrum. (Only speed constrained points can be selected)</td>
</tr>
<tr>
<td>Speed (set as reference) [rpm]:</td>
<td>If “Spectrum type” is defined as Factors, the reference speed to be multiplied with the factors can be entered. The user values from the nominal kinematic calculation are shown by default.</td>
</tr>
<tr>
<td>Torque defined to:</td>
<td>Select from list “SpeedOrForce” point where you want to define torque for spectrum. (Only torque constrained points can be selected)</td>
</tr>
<tr>
<td>Torque (set as reference) [Nm]:</td>
<td>If “Spectrum type” is defined as Factors, the reference torque to be multiplied with the factors can be entered. The user values from the nominal kinematic calculation are shown by default.</td>
</tr>
<tr>
<td>Use speed table for gear shifts:</td>
<td>Select if there are different speed / power flow shifts in the model (speed table should be in the model, if changed to &quot;yes&quot;, see documentation on the homepage)</td>
</tr>
<tr>
<td>Number of additional columns:</td>
<td>Set numbers of how many additional variables should be referenced and used in the calculation</td>
</tr>
<tr>
<td>Consider KHb factor:</td>
<td>Consider face load factor factor for each bin directly in the load spectrum table</td>
</tr>
<tr>
<td>Consider Kgam factor:</td>
<td>Consider k gamma factor for each bin directly in the load spectrum table</td>
</tr>
<tr>
<td>Consider YM (Kwb) factor:</td>
<td>Consider alternating bending factor for each bin directly in the load spectrum table</td>
</tr>
<tr>
<td>Input different temperatures:</td>
<td>Consider different temperature for each bin directly in the load spectrum table</td>
</tr>
</tbody>
</table>

#### 5.2.2 Manual definition

If “Manual definition” is chosen for field “Definition:” and “No. of Steps:” is defined, you will see empty load spectrum table with given number of load steps. User must then manually type in values for all steps.
Note! Values for frequency must add up to 1.00 if it is defined in fractions. If it is defined in percentage, the sum of the values must be 100. If the “Frequency type” was selected to be in “Hours”, the number of hours for every bin can be entered directly.

Regarding the definition of “Torque” and “Speed”: In case of “Factors” selection the torque and speed definition must be fraction of nominal values. In case of “Values” selections torque and speed should be defined using real values with correct signs.

5.2.3 Read from file

If “read from file” is selected for the field “Definition”, the user should pick up a generated file (*.csv). The file dialog is not automatically shown and needs to be manually opened by executing the function “ImportSpectrum” from the table.

Figure 7. Executing function “CreateSpectrum”
A text file with a load spectrum must have the following structure: Semicolon (;) as a separator of the fields, at least three values per line in order of “frequency/hours;torque;speed”. After that the file should contain gear name definition if needed and then all the additional values. See example shown below. This file can be directly generated from the Excel when saving format is selected to “*.csv”. Note order of the data in the file must be the same as seen in the table header after the definition.

The Spectrum is automatically created according to the selected file and will appear to main window as seen in Figure 6 Right. It is always possible to read in a file later even if manual definition is selected at the beginning. The length of the spectrum can also vary in different files and is not needed to be adjusted from the “DefinitionDialog” manually.

5.2.4 Spectrum type as absolute values

In case of definition with absolute values user must enter values in table (or in file to be imported) as real values without unit (e.g. 100 (Nm), 1000 (rpm)). It is very important to take care of signs of values in this case, because sign of the speed defines direction of rotation. Message box of reminder of that will also appear.
5.2.5 Spectrum type as Factors

If spectrum should be defined as factors, user must enter values in table (or in file to be imported) as fractions of nominal load. (e.g. 0.5 means that calculation is made with 0.5*nominal value or 1.2 means that calculation is made with 1.2*nominal value.)

5.2.6 Frequency type as Hours

The user can define the frequencies of the load spectrum directly in hours. In this case, the field for the Required lifetime will be deactivated as the lifetime is calculated from the defined frequencies.

5.2.7 Frequency type as Frequency fraction, Total = 1

The user can define the frequencies as the fraction of the required lifetime. In this case, the total sum of the frequencies should be 1. Note that you should not define the required lifetime with different values in other places, such as User interface or Settings window.

5.2.8 Attaching the load spectrum information to a load input and/or output

Use the fields “Speed defined to:” and “Torque defined to:” to define at which “kSysSpeedOrForce” element the speed and torque information as given in the load spectrum will be used.

5.2.9 Additional data in spectrum

Normally, the calculation of the load spectrum can be run when frequency, torque and speed are defined. There may anyway be cases where the model needs some extra definition (e.g. another input speed or activation of extra connection). In this case user can add additional columns to the spectrum to add these conditions.
The name of the additional column and the variable to be referenced can be defined using the dialog appearing. The column name can be different than the variable name:

As an example the x component of the centrical load on shaft “Shaft3” should change for each bin. In this case, it would make sense to set the variable name to “Fx_OutputShaft”, to select the CentricalLoad element on Shaft3 from the list and enter the variable name to be referenced. The centrical load element has to be added before to the model tree:

Additional information: If the “Additional expression” is set to yes, a formula where other variables are used can be entered. The result of this expression will then be multiplied automatically with the value in the load_spectrum table which is entered for the additional column and will be set for the referenced variable. In this case it is recommended to enter always 1 for every bin. It can be used for example to calculate the centrifugal force of a planet shaft which depends on the mass, the radius of the rotational circle and the angular velocity from every bin.

The load_spectrum table will look as followed, with the additional column called “Fx_OutputShaft”:

![Load Spectrum Table](image)
Additionally, KISSsys creates automatically a new array in the variables of the loadspectrum template:

![Created additional array in the Properties of the Loadspectrum_Template](image)

Figure 15. Created additional array in the Properties of the Loadspectrum_Template

5.2.10 Consider gear shifts

![Setting to consider gear shifts](image)

Figure 16. Setting to consider gear shifts

It is important to consider the different power paths in transmission gearboxes. To be able to calculate the kinematics in this case, the speed table is needed in the model. See the instruction on the KISSsoft homepage under “Templates” about how to add and use the speed table. Once this step is finished, by activating the setting in the DefinitionDialog, the different power paths can be considered in the load spectrum calculation as well.
KISSsys will create an additional column with the name “Gear”. This column can communicate with the different gears in the speed table.

Figure 17. Initial state of load spectrum table if gear shifts is considered

The same names of the different gears which are used in the speed table must be given in the “Gear” column:

Figure 18. Definition of the speed table

Figure 19. Definition of the load spectrum table with the different gears

According to the load steps, the order of the gears can be also different.

**Important:** The reference will not work correctly, if more than one speed tables is used in the model. In this case, either remove the other speed tables or change the reference in the SetLoad function of the load spectrum template under “SHIFTING GEAR DEFINITION SETTINGS”.

5.2.11 Consider KHb factor

If the setting is active, the face load factor factor for each gear calculation can be considered in the load spectrum table:
Figure 20. Change setting to consider KHb factor

Figure 21. Settings for KHb factor for each calculation

Figure 22. Changed settings to be able to enter KHb factor for every bin

Figure 23. Additional columns in load spectrum table to control the KHb values for each bin
5.2.12 Consider Kgam factor

If the setting is active, the k gamma factor can be considered in the load spectrum table for planetary stage calculations and for gear pair calculations where “kgam” variable is set to a value different than 1.

Figure 24. Change setting to consider KHb factor

5.2.13 Consider YM (Kwb) factor

If the setting is active, the alternating bending factor for each gear pair calculation can be considered in the load spectrum table:

Figure 25. Change setting to consider alternating bending factor
The user has the same options as in KISSsoft side. If selected Own input, per load spectrum bin, user can control the values directly in the load spectrum table:

5.2.14 Input different temperatures

If the setting is active, the different temperatures for each load bin can be considered in the gear calculations:
5.3 ImportSpectrum

This function can be used to read in spectrum data from a created file (*.csv). The file dialog is not automatically shown even if “read from file” is selected in “DefinitionDialog” and needs to be manually opened by executing the function “ImportSpectrum”- from the table.

Note! Be careful that data is defined similarly in the file as in the definition dialog. If all the information is not available in the file fields are left empty. For more info see chapter 5.2.1. It is always possible to read in a file later even if manual definition is selected at the beginning. The length of the spectrum can also vary in different files and is not needed to be adjusted from the “DefinitionDialog” manually.

5.4 ExportSpectrum

The load spectrum information can be written in a “*.csv” file including the header. This file can be read back to the spectrum with the “CreateSpectrum” function without any modifications.
5.5 “Calculate” → “CalculationDialog”

Once the spectrum has been set up as shown above, calculations can be executed using function “CalculationDialog” under “LoadSpectrum” from tree structure.

![CalculationDialog](image)

**Figure 32. Executing the “CalculationDialog” in the LoadSpectrum template**

Since 2016, a specific button was created to call this function directly from the interface if there is at least one load spectrum template defined in the model. If there is more than one, then the user has to select which one to calculate with (be careful to the button below, the one on the left side of it is to calculate a database defined load spectrum, not from the template).

![Select load spectrum template](image)

**Figure 33. Executing the “CalculationDialog” from the interface**

The following dialog will appear to be able to select different calculation types:
Table 4 Calculation types that can be selected in using "CalculationDialog"

<table>
<thead>
<tr>
<th>Settings</th>
<th>Selection</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type of calculation</td>
<td>Reference load</td>
<td>Calculation with the nominal load that user has initially defined for the model (before defining a load spectrum). This does not really use load spectrum for calculation, but can be used instead of separate calculation function for single load stage. Calculation procedure is also predefined and stores results to the same variables as with load spectrum calculation.</td>
</tr>
<tr>
<td></td>
<td>Single load bin</td>
<td>User may select one load step out of the spectrum and calculate with that value. Load case number needs to be set in the field below the selection.</td>
</tr>
<tr>
<td></td>
<td>Full load spectrum</td>
<td>Calculates model with given spectrum. Results for every bin and final results are exported after the calculation.</td>
</tr>
<tr>
<td>Select single load bin</td>
<td>Select the number of load bin for the first type of the calculation above.</td>
<td></td>
</tr>
<tr>
<td>Export KISSsoft calculation file?</td>
<td>If set to “Yes”, all KISSsoft calculations in the model will be exported with the spectrum inside to the model folder. They can be opened separately and analyzed in KISSsoft after the calculation.</td>
<td></td>
</tr>
<tr>
<td>Check multiple mesh gears?</td>
<td>Can be activated if the special results for multiple meshes should be written out.</td>
<td></td>
</tr>
<tr>
<td>Generate an open full KISSsoft report?</td>
<td>Generates and opens the full KISSsoft report automatically after finishing the calculation</td>
<td></td>
</tr>
<tr>
<td>Consider power loss from efficiency template?</td>
<td>When an efficiency template is defined in the model, the user has the possibility to consider the power loss elements automatically created by it, for each bin of the load spectrum calculation</td>
<td></td>
</tr>
<tr>
<td>Consider housing stiffness?</td>
<td>When a stiffness matrix is defined in the model (using a casing element), the user has the possibility to consider the offsets</td>
<td></td>
</tr>
<tr>
<td>Calculations</td>
<td>Description</td>
<td></td>
</tr>
<tr>
<td>--------------</td>
<td>-------------</td>
<td></td>
</tr>
<tr>
<td>Execute modal analysis?</td>
<td>If set to “Yes”, results for modal analysis can be written out for every load step.</td>
<td></td>
</tr>
<tr>
<td>Execute contact analysis?</td>
<td>Contact analysis can be executed for every bin of the loadspectrum calculation. The PPTE value can be found as a result for every step.</td>
<td></td>
</tr>
<tr>
<td>Select calculations</td>
<td>Allows the user to calculate with load spectrum for all elements or just gears or just shafts and bearings.</td>
<td></td>
</tr>
<tr>
<td>Calculation comments</td>
<td>Allows the user to add a comment in the “Results” and “Damages” files.</td>
<td></td>
</tr>
</tbody>
</table>

5.5.1 Reference load
The program calculates the model with nominal load which user has defined for the model. The results for lifetimes and safety factors are available. It is recommended to use this calculation method instead of KISSsys default calculation method, to ensure that results will be presented in same variables as with other calculation methods and are automatically written out.

5.5.2 Single load bin
With this calculation user should select one line/step from load spectrum model to be calculated as a single load. After calculation, the load is kept in the model. If the user wants to calculate with initial nominal load, he should calculate with reference load (previous selection).

5.5.3 Full load spectrum
Results are generated using the complete spectrum. This calculation method performs a damage accumulation using Miner rule over the load spectrum. Safety factors for gears are calculated according to spectrum as well as lifetimes for gears and bearings. Additionally, single lifetimes of every step are saved for later use. Damage values for each load step in the load spectrum are also calculated. After calculation user defined nominal load is set back to model.
Before the calculation user should take care of application factors for gears (KA). These should be set to 1, but also different values are possible depending on place of the gears in the power train.
The result files are saved in the project folder in an additional folder named “FileName_Date_Time”:

![Created files in the project folder](image)
5.5.4 Export KISSsoft calculation file

Calculation will be done according to the chapter 5.5.3. In addition, the KISSsoft calculation files for each bin are saved in the project folder. This option can be used to debug an existing inconsistency in the load spectrum calculation. The user can check each gear and shaft calculation. KISSsys is creating a folder named SingleCalculations, where the KISSsoft files and the load spectrum data files are saved.

![Image showing SingleCalculations folder]

This gives the user the possibility to read in the spectras in KISSsoft, to check or debug the calculation. The KISSsoft files are automatically saved with the corresponding load spectrum data file for the gears, or directly with the load spectrum definition in the corresponding elements of the shafts. Then, the KISSsoft file is exactly the same as used in KISSsys load spectrum calculation.

Note: All KISSsoft calculations will have entered a nominal speed of 100 rpm and a torque of 100 Nm for the rating of the force elements. This is done internally on purpose. The factors in the spectrum are adapted accordingly automatically in order to have the correct rating as defined from the user.

6 Calculation results

After using any of above described calculations results are saved in default KISSsys values. E.g. gear safety factors SF1 and SH1 are according to the spectrum if spectrum calculation was selected.

6.1 Result files

After the calculations external result files are created for more detailed results investigation. These files are located in the project folder. Files are called “Results.csv” and “Results.txt” including all the calculation results. Further files “Damages.csv” and “Damages.txt” are created to show damages of gears and bearings. MultiplemeshResults.csv is written out if there is such a situation in the model and it is activated in the “CalculationDialog”.

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12.06.2018
6.1.1 Lifetimes and safety factors according to the calculation

An external “Results.csv” file is automatically created if calculation is performed with the load spectrum. In this file, all the safety factors and lifetimes for each step are shown. Also, frequency, torque and speed values for every gear stages are shown. The user can see the weakest components for each bin and the utilization at the end of the file. This file is located in the project folder.

6.1.2 Damages with Spectrum calculation

External “Damage.csv” file is automatically created if calculation is performed with the load spectrum in details. In this file, the partial damages in percentages [%] against required and against calculated lifetime for all steps in the load spectrum are listed. This file is located in the project folder.
<table>
<thead>
<tr>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
<th>E</th>
<th>F</th>
<th>G</th>
<th>H</th>
<th>I</th>
<th>J</th>
</tr>
</thead>
<tbody>
<tr>
<td>Note:</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.0e+20 (lifetimes for gear) : infinite lifetime</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.0e+06 (lifetimes for shaft and bearing) : infinite lifetime</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
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Figure 40. “Damages.csv” with partial damages, opened in Excel